EXPERIENCES FROM REPEATED MEASUREMENTS IN SWEDISH SCHOOLS AND MULTI-FAMILY HOUSES

- Present recommendations and requirements about repeated measurements.
- Measurements in schools and preschools/daycares.
- Measurements in multi-family residential building
- Differences in repeated measurements between municipalities
- Conclusions and discussions

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Present recommendations and requirements about repeated radon measurements

Sweden (Swedish Radiation Safety Authority)

Recommendation on their web-page

- Construction work has been carried out that may affect radon levels
- It has been more than 10 years since the last measurement was taken.

Required for registered workplaces with levels above 200 Bq/m^3 during working hours before re-registration which is required every 10 years.

Canada (Health Canada)

- Post-mitigation re-testing every 5 years.

US (recommendations from radon professionals/companies)

- Re-testing every 2-5 years.

Recommendations about re-testing are usually not found in radon measurement protocols.

Data sources

Data has been obtained from:

- **Database of Radonova** with radon measurements since 2004. Repeated measurements were evaluated when the original measurements were done during 2010-2015 and the repeated measurements were made at least 6 years afterwards (in average about 10 years).
- **Statistics Sweden's (SCB)** statistical database with information on apartments and single-family homes, https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/.
- **The Swedish National Agency for Education's** statistical database containing data on the number of schools and preschools, https://statistikdatabasen.skolverket.se/PxWeb/pxweb/sv/Skolverkets_statistikdatabas/

Data is missing for alternative providers of radon measurements, which may affect conclusions at the individual municipal level but should not affect general conclusions.

Measurements in Swedish Schools & Preschools

Swedish long-term measurements analyzed by Radonova (no data available for 20 % of the 290 Swedish municipalities)

It is difficult to determine the number of buildings used for schools and preschools

- According to the Swedish Agency for Education: 5164 elementary and high schools (how many buildings)
- According to AI: 17600 schools and preschools

Building type	Measured 2003-2014	Measured 2015-2025
School	8280	8104
Preschool/Daycare	6770	6665
Total School & Preschool/Daycare	**15050**	**14769**

Very consistent and high number of measurements over time for Schools & Preschools

What about repeated measurements in Schools & Preschools?

Swedish workplaces – different categories

Radon long-term measurements with 5 or more measure points – analyzed 2017-2020.
Reference level in Sweden is 5.4 pCi/L (200 Bq/m^3)

Workplace type	Number of work-places	Average no. of measure points	Average Median value (pCi/L)	Average (pCi/L) & (Spreading)	Median above 5.4 pCi/L	Some value above 5.4 pCi/L (**)	Highest value(*) (pCi/L)
Total	3347	12.5	2.1	2.9 (75 %)	7.1 %	34 %	> 950
Office	639	14.1	2.2	3.9 (78 %)	6.6 %	35 %	330
Industry	307	13.4	2.1	2.7 (75 %)	9.4 %	31 %	> 950
School	**1005**	**12.7**	**2.1**	**2.8 (81 %)**	**6.0 %**	**40 %**	**600**
Kindergarten - Preschool	**665**	**9.0**	**1.7**	**2.0 (60 %)**	**4.5 %**	**24 %**	**89**

Most (> 90 %) schools and workplaces have time-controlled ventilation where the radon concentrations during occupied hours can be significantly lower compared to a long-term average value.

(*) all measure points analyzed 2018-2020
(**) 2018-2020 all 11’000 workplaces: 24 % of the workplaces had some value above 200 Bq/m^3

Follow-up measurements in workplaces and schools

Swedish long-term measurements during 2021-2025 from the database of Radonova and possible 7-days follow-up measurements (507 measurements) to estimate the average radon concentrations during working hours.

An estimated long-term average during occupied hours in a building with time-controlled ventilation could be obtained by multiplying a previous long-term value with a factor between radon levels during occupied hours and the entire measurement period in a follow-up CRM-measurement of **7 days**.

Building type	Long-term measure points above 5.4 pCi/L	Number of follow-up measurements (*)	Invalid follow-up measurements (**)	Corrected annual average <= 5.4 pCi/L	Factor (average value)
School	**4561**	**180 (2.7 %)**	**11 (6.1 %)**	**132 (78 %)**	**0.37**
Preschool	**1787**	**72 (4.3 %)**	**6 (8.3 %)**	**59 (89 %)**	**0.37**
Industry	1943	80 (4.4 %)	4 (11.1 %)	45 (59 %)	0.64
Office	2690	53 (2.1 %)	10 (18.9 %)	31 (72 %)	0.47
Total	15719	507 (3.5 %)	47 (9.3 %)	314 (68 %)	0.48

(*) It has been considered that 6.7 % of the measurements have natural ventilation and cannot be included in follow-up measurements.
(**) The reason is often a significantly abnormal low average value for the entire follow-up measurement period; it is likely that the customer has had the ventilation running the entire time.

Repeated measurements in schools and preschools

- Preschools with at least 3 measure points and schools with at least 5 measure points in the buildings, both in the original and repeated measurements, were selected.
- The average times between the original and repeated measurement in this data sets were 9.8 years (preschools) and 8.3 years (schools)

Workplace type	Number of measurements	Measurements with values above 5.4 pCi/L (original)	Measurements with values above 5.4 pCi/L (repeat)	Repeat measurements with values above 5.4 pCi/L with no original value above 2.7 pCi/L	Highest repeat value (pCi/L) with no original value above 2.7 pCi/L
Preschools	87	21	22	8 (16 %)	24.1 pCi/L
School	89	46	46	2 (2 %)	10.7 pCi/L

- **Schools which usually are quite large buildings seems to have smaller variations in radon concentrations with time compared to preschools.**
- **Both schools and preschools have in average more measure points in the repeated measurements compared to the original measurements, for preschools an increase from 5 to 10 point and for schools an increase from 11 to 15 measure points.**
- **In a few cases for both schools and preschools, “new” high values are found.**

Measurements in Swedish multi-family buildings

(Long-term measurements analyzed by Radonova 2015-2025)

Municipality	Number of apartments	30 % of the apartments (*)	Measured (*)	Average value (pCi/L)	Highest value (pCi/L)	Above 5.4 pCi/L
Total	2746715	824015	44.5 %	2.2	203	10.1 %
31 % of the municipalities	Average 4834		< 20´%	2.4		
22 % of the municipalities	Average 7223		> 70 %	2.5		
Stockholm	433821	130146	58.2 %	1.9	126	6.6 %
Malmö	142873	42862	29.7 %	0.7	15	0.4 %
Uppsala	75730	22719	90.1 %	2.0	110	8.3 %
Karlstad	32854	9856	39.3 %	2.6	46	15,4 %

(*) Percentage measured of 30 % of the apartments (all apartments with ground contact and 20 % of the rest should be measured).

- **There is no significant difference in radon levels between municipalities where measurements are taken frequently and those where they are taken less often.**
- **In municipalities with a larger number of apartments, the percentage measured is higher.**

In general, a very large number of measurements in Swedish multi-family houses!!

Repeated measurements in multi-family buildings

- Long-term measurements with at least 5 measure points in the multi-family “building”, both in the original and repeated measurements, were selected.
- The average time between the original and repeated measurement in this data sets was 10.2 years. (preschools) and 8.3 years (schools)
- 362 (65 %) of the 559 buildings with repeated measurements were included in the evaluation.

Measurement set	Average no. of measured apartments	Average radon concentration (pCi/L)	Apartments above 2.7 pCi/L	Apartments above 5.4 pCi/L
Original (2010-2015)	15	2.1	184 (51 %)	106 (29 %)
Repeated (6+ years)	17	1.8	186 (51 %)	85 (23 %)

- **Only small differences between the original and repeated measurement were observed.**
- **Of the buildings where all apartments had values below 2.7 pCi/L, only 2 (1.1 %) values above the Swedish reference value of 5.4 pCi/L in the repeated measurement.**

Repeated measurements in Swedish municipalities

9.4 % of the Swedish population of 10.6 million people live in the municipality of Stockholm (2026)

Building type	Municipalities in original measurements	Measurements in the municipality of Stockholm (original)	Repeated in defined time region (% of original) (*)	Repeated outside defined time region (% of original)	Municipalities in repeated measurements	Measurements in the municipality of Stockholm (repeated)
Preschool	72	123 (34 %)	164 (45 %)	20 %	36	90 (55 %)
School	65	189 (47 %)	160 (40 %)	36 %	33	100 (62 %)
Multi-family	175	583 (17 %)	559 (16 %)	38 %	84	91 (16 %)

In general, repeat measurements in schools and preschools are more frequently done in larger municipalities as in the City of Stockholm but with large variations between municipalities.

(*) About 60 % of the original measurements in schools and preschools had not sufficient address information.

Repeated measurements in Swedish Single-Family houses

Data from “original” measurements during the season 2011/2012.

Repeated measurements after at least 6 years in houses with no mitigation.

Data from “original” measurements during the season 2011/2012, where 6732 measurements (about 40 %) of 13786 measurements had more than one measurement for that house.

- In average, the houses with repeated measurements had about 3 measurements (preliminary number) of which many are post-mitigation measurements.
- 31 % of the “repeat measurements” had no annual average calculated (short-term measurements).
- 34 % of the 960 repeat measurements after 2018 are done in houses where it is stated “no mitigation”
- 45 % of the “repeat measurements” are done in houses where it is stated “mitigation”.

Repeated measurements in Single-Family houses

Data from “original” measurements during the season 2011/2012.

Repeated measurements after at least 6 years in houses with no mitigation.

Radon levels in ”original” measurement	Number of ”original measurements”	Repeat measurements above 5.4 pCi/L
< 1.4 pCi/L	36	0
1.4 pCi/L – 2.7 pCi/L	41	1 (2.4 %)
2.7 pCi/L – 4.1 pCi/L	35	3 (8.6 %)
4.1 pCi/L – 5.4 pCi/L	37	10 (27 %)

When is it motivated with a repeated measurement?

Summary and conclusions

- **The municipalities' control of radon testing in multi-family buildings and schools/preschools are, overall, working very well in Sweden**
- There appear to be significant differences from municipality to municipality how frequent re-measurements are made or required at all.
- On average, there are no significant differences in radon levels between municipalities where many measurements are made and those where few measurements are made.
- It seems that the increased radon awareness from a first measurement gives more measured points and/or measured buildings in the repeated measurements.
- Larger buildings (schools and multi-family houses) seems to have smaller variations with time compared to smaller buildings (preschools and single-family houses).

THANK YOU !!

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